Radioastronomy and Amateur Radio services: common challenges toward top levels in technical knowledge, system sensitivities and social compatibility

CRAF **(Committee of Radio Astronomy Frequencies)**

is an *Expert Committee* of the

EUROPEAN SCIENCE FOUNDATION

INAF ISTITUTO NAZIONALE DI ASTROFISICA

RadioNet

RadioNet collects all of the Europe's leading astronomy facilities in getting funds from the European Commission.

Network Activity for ***Spectrum Management***

SRT SARDINIA RADIO TELESCOPE

I4AOR, Roberto Ambrosini

E-mail: ambrosini@ira.inaf.it

URL: www.craf.eu

Amateur Radio vs Radiostronomy

Personal education	Fundamental research
No profit	***No profit***
Best ideas (*smart and cheap…*)	Top technology (*driver & user*)
Sporadic / Rare events	Forefront of knowledge
No ***time*** limitation	***Budgetary constrained*** (but not commercially limited)
Tx + Rx : Active and Passive –Antennas, Tx, Rx, Data handling..	PASSIVE only –Antennas, Receivers, Data handling..
Need for better strategies on Spectrum Management	

Two common concerns:

1) Recently UK and France Administrations have imposed radio astronomy

to pay

for the usage of the spectrum, as a balance with respect to its ***"commercial value"***, determined by other telecomm applications.

How is it possible to ***commensurate:*** ***Personal Education and/or Science with the industrial profit?***

- ***time scale evolution*** of a discovery
- long term societal fall out of ***self learning***

– RA and radio amateurs have to ***JUSTIFY*** their spectrum usage!!!

- ***Even if*** radio astronomy would be forced to an untimely ***death***, it would not provide a "panacea" for the other users.It would simply mark the first victim of a deregulation regime where the reliability of any radio service would ultimately be affected.

2) Threads from unlicensed usage of ***poor quality*** Ultra Wide Band emitters.

sooner or later they will affect not only the high sensitivity receivers used at radio astronomy observatories, but all other radio services.

Finally don't forget that the ***European Commission*** has realized the huge economical value of the radio spectrum and is going to take a ***strong political leadership*** on it.

SRT – present status

http://srtproject.ca.astro.it/welcome

IY2009

The International Astronomical Union (**IAU**), **UNESCO** and the **United Nations** have proclaimed 2009 as the International Year of Astronomy (IYA2009) under the theme "**The Universe, yours to discover**".

It will be a ***global celebration*** of astronomy and its contribution to society and culture, with a strong emphasis on education, public engagement and the involvement of young people, with events at national, regional, and global levels throughout the whole of 2009.

ESF EUROPEAN SCIENCE FOUNDATION will be one of the

Organisational Associates

- **Dark Skies Awareness**

CRAF has proposed to extend its aim in:

Dark and Quiet Skies Awareness

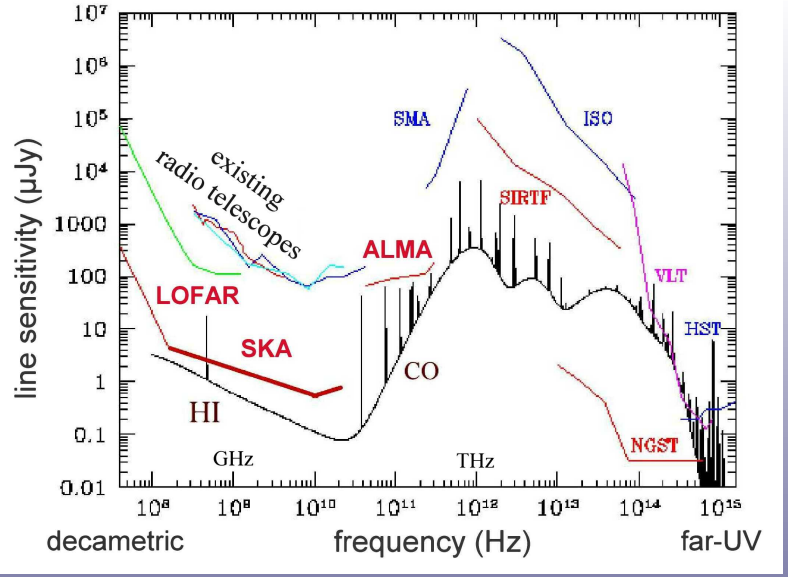
http://www.astronomy2009.org

Be quiet please……

Thanks you for your attention……

New generation of radio telescopes

- **LOFAR (**Low Frequency Array)
  10 – 240 MHz under completion 2008
- **SRT (**Sardinia Radio Telescope**)**
  0.3 – 100 GHz in construction 2009
- **ALMA (**Atacama Large Millimetre Array)
  31-950 GHz funded 700 M€ 2012
- **SKA (**Square Kilometre Array)
  0.15-25 GHz R&D 1000 M€ 2020



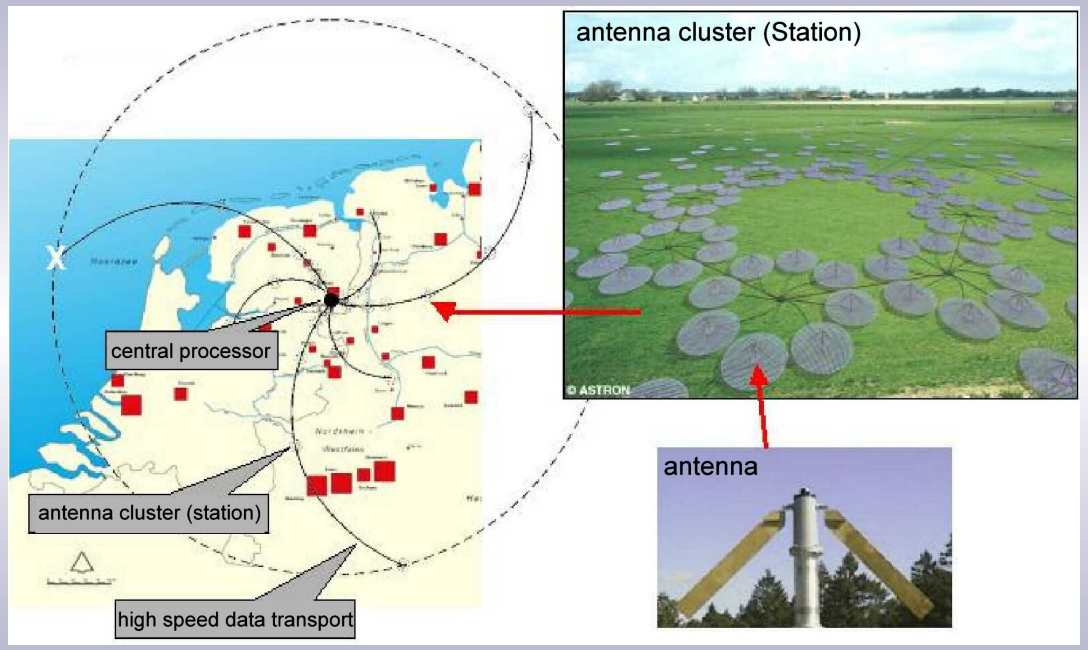
Sensitivity raised by 10^5 in 60 years:

a doubling factor every 3 years

- Breakthrough needed in sensitivity
- Widening in frequency coverage

Interference Mitigation, multi-beam operation with adaptive nulling

LOFAR (Low Frequency ARray)



- 10-240 MHz range
- 25,000 antennas
- first 1500 funded, spread over 100Km
- largest final baseline: 350 km
- 1 km² total collecting area
- no moving parts
- multiple beams
- pointing and frequency agility

core located in The Netherlands with remote stations outside

ALMA (Atacama Large Millimetre Array)

http://www.alma.nrao.edu/

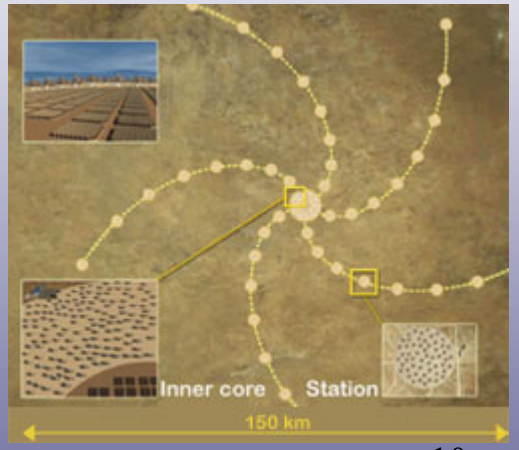
- 31-950 GHz range
- 64 antennas of ~12 m diameter
- baselines up to 35 km
- high and dry: 5000 m high desert

SKA (Square Kilometre Array)

- 0.15-25 GHz range
- X00 “stations” (core / outliers)
- largest baseline: 4000 km
- 0.01 arcsec spatial resolution at 1.4 GHz
- 1 km^2 total collecting area
  multiple beams / large field-of-view
- extreme pointing agility

site: Australia or South Africa

www.skatelescope.org



The array configuration will include a compact core with about 50% of the collecting area within 5 km, an extended array containing about 75% of the collecting area within 150 km, and the rest in various distant stations out to at least 3000 km.

Radio astronomy (RA) is susceptible to Radio Frequency Interference (RFI)

Interference to the detection of the RA observables:

- originate from a terrestrial or satellite origin (fixed/movable directions)
- are directly emitted in the RA bands (rather easy identification)
- or fall into them as spurious and/or unwanted emissions (very difficult to identify and to find a compatibility)
- Modern observations often look at high redshifts (receive very well outside the RA bands)

Need for ***protection strategies***:

- receivers with high dynamic range, antennas/arrays with low sidelobes
- new mitigation techniques (like: multiple adaptive antenna beams in real time, auto recognition of interferes, interferometric anti-correlation, noise excision, etc)
- definition of Radio Quiet Zones around the telescope sites
- ***SPECTRUM MANAGEMENT trough regulatory measures:***

"prevention is better than a cure"

Differences between Passive and Active Communication Services

	Passive	Active
Transmitting Power	Weak natural sources	Selectable
Transmitting Frequency	Determined by the observable	Selectable
Receiver Frequency	Determined by the observable	Selectable
Receiving Sensitivity	From best to ultimate	Selectable
Cabled (=non wireless) alternative	NO	Yes
Commercial Value	?!?!?!?!?!	Huge

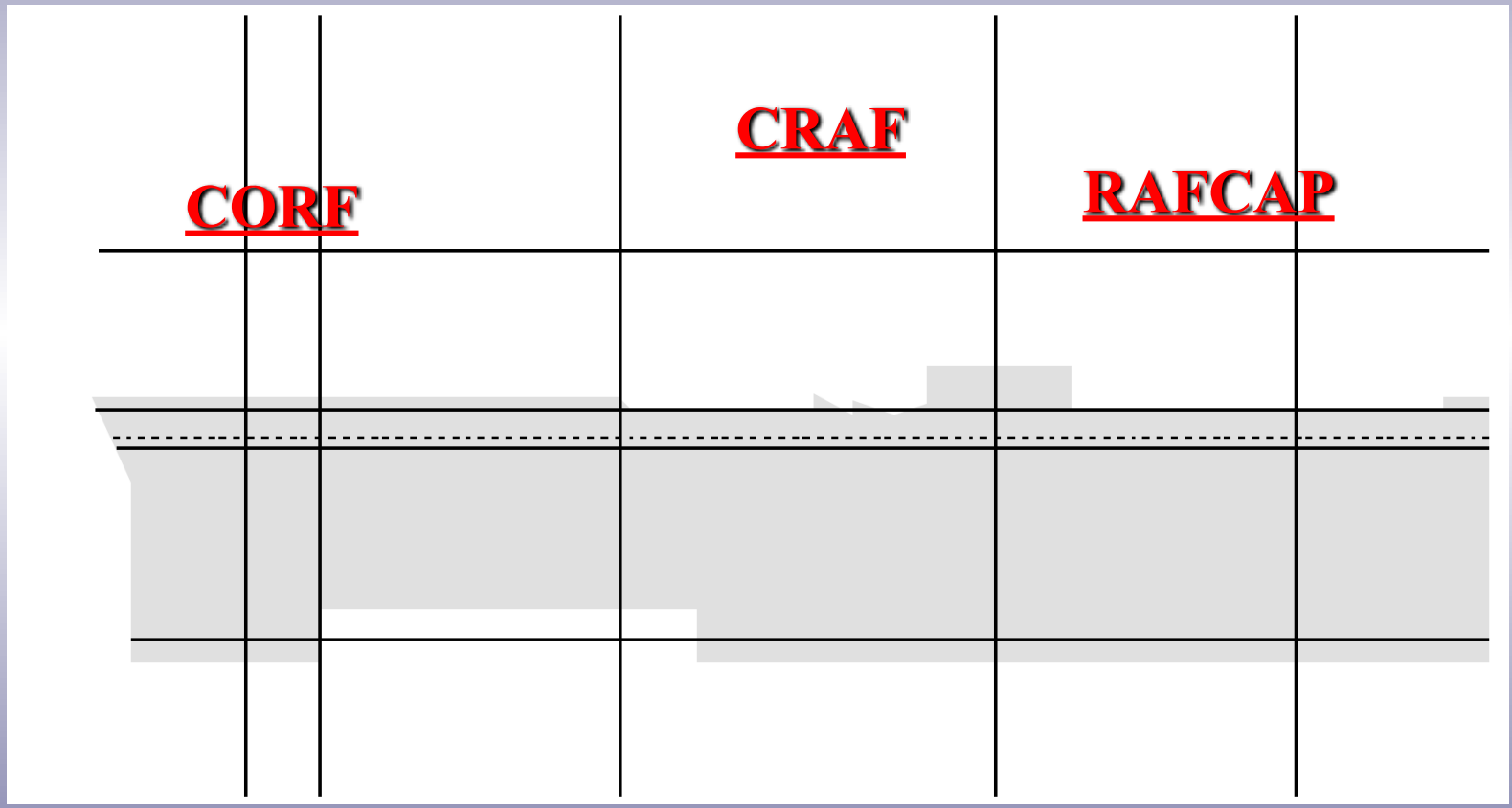
Protection from interferences

- ***Internationally*** ITU-R RA.769 gives the detrimental levels to RA observations (typ. values are 10^{-26} W/m^2/Hz)
- Protection should be enforced by ***National Administrations.*** In Europe now the ***European Commission*** has coordination rights on all of them.
- Often Observatories have to detect ***by their own*** the source (local or remote, terrestrial or from satellites)

Then there are four levels of actions to be taken:
International (ITU → IUCAF), European (CEPT → CRAF), National (CRAF members), Local (Observatory technicians)

RA committees over the ITU-R Regions

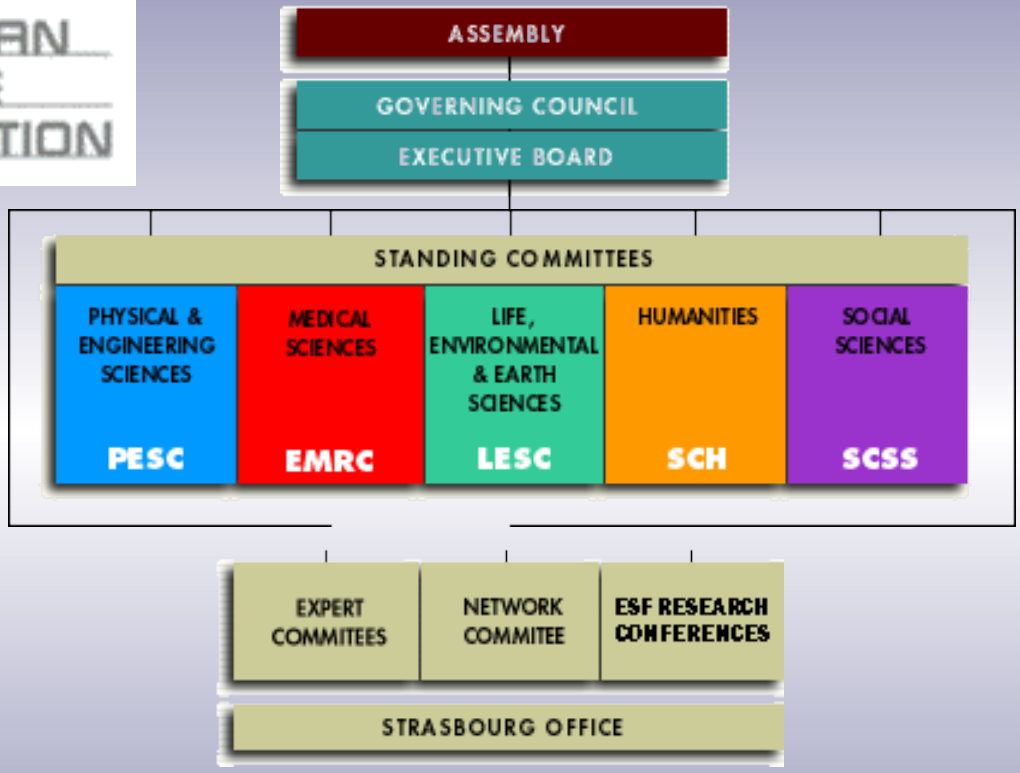
IUCAF



African bloc: *only RAS in South Africa*; **Arab bloc**: *no radio astronomy*

CRAF in practice: I part

78 Member Organizations



One of the Expert Committe of PESC is:

CRAF, Committee for Radioastronomical Frequencies

CRAF in practice: II part

CRAF is made of

- ***CRAF members,*** *each from one of the* ***18 EU Member Institutions*** + South Africa
  being Greece the last to join us
- ***ESF Liaison (Thibaut Léry) + Secretary (Carole Mabrouk)***
- ***Frequency Manager (Laurentiu Alexe)***
  - full-time position; funded by Observatories/Agencies (not EC), through ES
- ***CRAF secretary (Pietro Bolli)***
- ***CRAF chair (Roberto Ambrosini)***

CRAF activity

CRAF has the status of: Observer in CEPT, Sector Member in ITU, so it participates to:

- ***ECC Working Group FM, ECC Working Group SE, FM and SE project teams….***
- ***World Radio Conference, ITU study groups, Working Parties (7D Radio astronomy, etc)***
- 2 ***Plenary*** meetings and 2 ***Newsletters*** per year;
- a well established ***Website*** ***http://www.craf.eu*** made of many hundreds of pages
  (docs, formulas, specific and general info)
- 2 ***Handbooks (published by ESF)*** :
  CRAF handbook for Radio Astronomy (new edition 2005);
  CRAF Handbook for Frequency Management;

CRAF special events

2004 ***:"Active Protection of Passive Radio Services: towards a concerted strategy", Cagliari, (I)***

2005 : ***" II Summer School on Frequency Management", C.S. Pietro, BO (I)***

2009 : ***"III Summer School on Frequency Management", Corea***

The European environment

The ***European Commission*** has realized the huge economical value of the radio spectrum and is going to take a ***strong political leadership*** on it.

Recently radio astronomers have been asked to justify the (passive) usage of their spectrum allocations in terms of ***"commercial values".***

- How is it possible to ***commensurate Science with the industrial profit?***
- ***How can we evaluate our parents?***

(Science is the mother of all modern technical achievements)

Firstly consider the ***time scale evolution*** of a discovery in fundamental science: its translation into an usable application, the realization of an engineering prototype and finally the production of a consumer device ***usually takes decades***.

- How can you compare it with ***selling now a telecom licence?***

As a matter of facts now UK and France Administrations have imposed radio astronomy to pay for the usage of the spectrum.

Conclusive remarks (1)

- What radio astronomy really needs:
  - to keep the ***same protection levels now granted*** by RA. 769 and the ***present "exclusive"*** allocation of very few frequency bands (S.5340).
    - spectrum claimed: ***less than 2%,*** mainly centred on natural emission lines
    - this will guarantee the present level of ***sensitivity*** of the European telescopes
    - it will allow accurate calibration of our observations and correct evaluation of the efficiency of the new mitigation techniques
  - enforcement of ***"radio protection zones"*** around our telescopes.
    - the area we claim is a small fraction of the territory, well ***separated from the civilian "hot spots"***.
  - Rejection of the unlicensed usage of poor quality Ultra Wide Band emitters.
    - sooner or later they will affect not only the high sensitivity receivers used at radio astronomy observatories, but all other radio services. ***Something built on the cheap today, cannot be the best strategy for spectrum management of the future.***

Conclusive remarks (2)

Does the radio spectrum really belong to Society?

If you answer yes, radio astronomy can offer to Society:

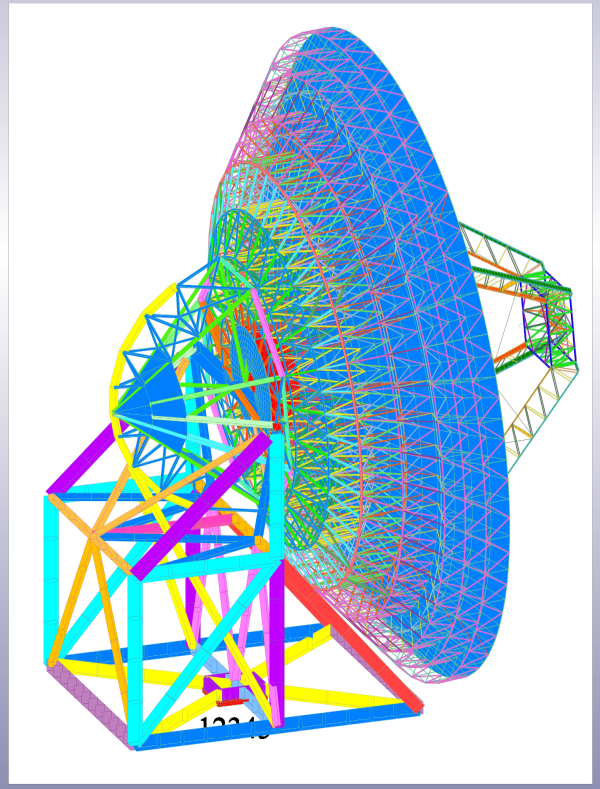
- a ***driving force*** for the most advanced technological developments
- a better understandings of the Universe and many good ***learning*** pathways (all grades)
- being passive services the most vulnerable class of radio spectrum users, they are the most credible ***verifiers*** that the value of the radio spectrum to Society is ***not misused*** by the more powerful ones (the active services).
- ***Even if*** radio astronomy would be forced to an untimely ***death***, it would not provide a "panacea" for the other users.
  - It would simply mark the first victim of a deregulation regime where the reliability of any radio service would ultimately be affected.

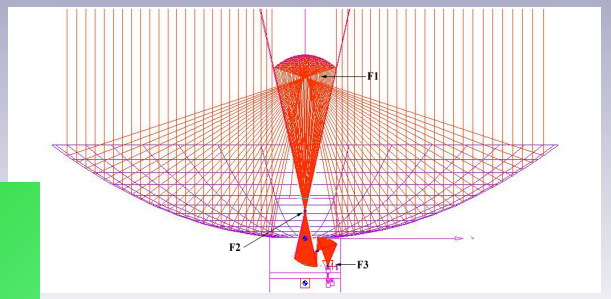
Radio astronomy is looking for a ***compatibility*** among all radio services.

This result can be achieved only if appropriate rules are updated now and strenuously enforced.

SRT: Sardinia Radio Telescope

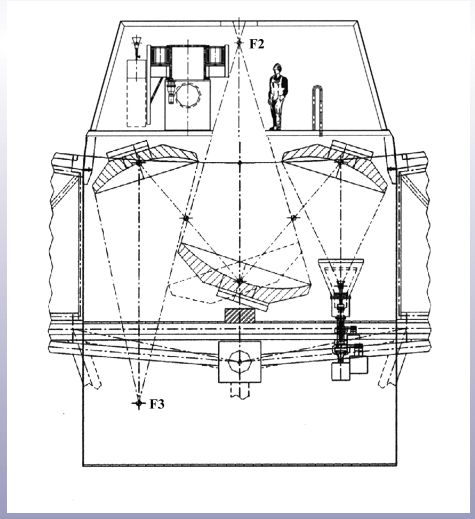
SRT will be the most powerful Italian radio telescope and one of the most sensitive, efficient and versatile, as a single dish antenna





KEY parameters:

large collecting area
(D=64 metres)
wide frequency coverage
(0.3 –100GHz)
advanced design:
active surface,
metrology system,
three foci,
FEA, some homology
Shaping: low Tsys, SWR



Two aspects of our activity:

Estimate of Radio Astronomincal Data Loss from Interference on Spectroscopic Measurements

A. Jessner, MPIfR Effelsberg, 12.September 2007

RFI threshold:
A spectrum obtained after an integration time t_{int} is considered to be affected by interference, when one or mo spectral channels, each of bandwidth Δv, show signals of human origin that exceed the limits for spectroscopy by RA 769.For different integration time and bandwidth the RA 769 limits will have to be adjusted according to the radiometer equation by

$$-5\cdot\log\left(\frac{t_{int}}{2000\ s}\right)-5\cdot\log\left(\frac{\Delta v}{\Delta v_{769}}\right)\quad dB$$

Here Δv_{769} is the reference bandwidth of ITU-R RA 769.

Total loss of observation time for one session:

The total loss of observing time t_{rfi} is the sum of all t_{int} of all the sessions where the rfi threshold had been exceeded in at least one spectral channel.

$$t_{rfi}=\sum_{n=1}^{N_{obs}} t_{int}(n)\cdot(rfi>Limit)$$

Here N_{obs} is the total number of observations in a session and N_{rfi} is the number of observations where rfi exc the threshold in at least one spectral channel.

Rate of Data loss:

The rate of data loss is the mean probability of observing a spectrum where rfi exceeds the threshold in at least channel. It is given according to Laplace's rule of succession as:

$$p_{loss}(N_{obs},N_{rfi}):=\frac{N_{rfi}+1}{N_{obs}+2}$$

The standard deviation of the mean probability is given by:

$$\sigma_{loss}(N_{obs},N_{rfi}):=\frac{\sqrt{(N_{obs}-N_{rfi}+1)\cdot(N_{rfi}+1)}}{(2+N_{obs})\cdot\sqrt{3+N_{obs}}}$$

Probability of data loss rate exceeding a critical value p_{crit}:

the probability of the data loss rate being below a critical value is given by the cumulative beta distribution

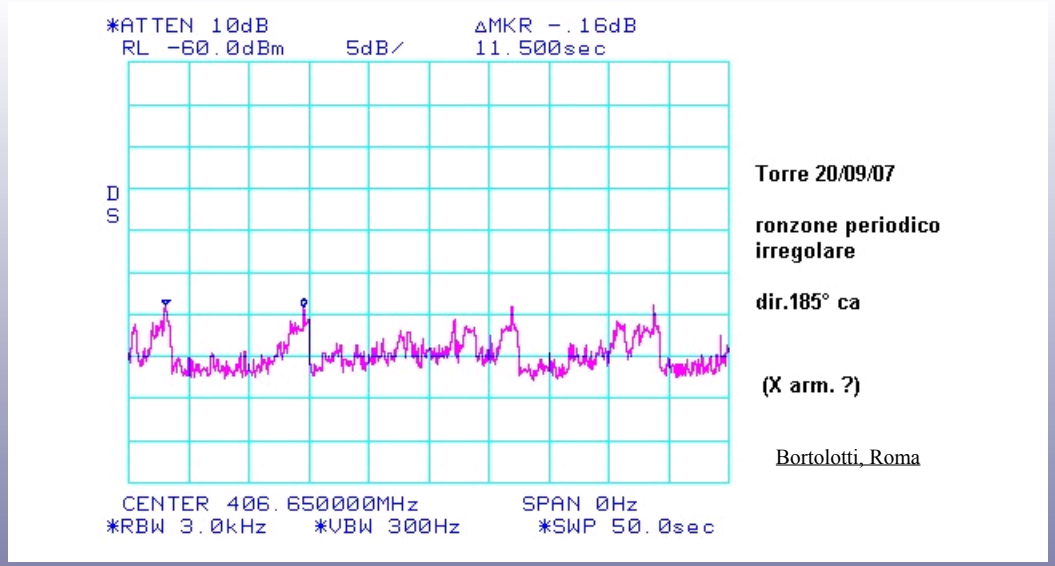
$$P(p_{crit},N_{obs},N_{rfi}):=\frac{\Gamma(N_{obs}+2)}{\Gamma(N_{obs}-N_{rfi}+1)\cdot\Gamma(N_{rfi}+1)}\int_0^{p_{crit}}\theta^{N_{rfi}}\cdot(1-\theta)^{N_{obs}-N_{rfi}}\,d\theta$$

-1-

Background theory on Data Loss

The Practice:

406.650 MHz emission from the 10th Harmonics of the Tx/Rx by Chicco /Artsana, Baby Control



Torre 20/09/07

ronzone periodico irregolare

dir.185° ca

(X arm. ?)

Bortolotti, Roma

Strategies applicable for the protection of our Observations

2. Day by day monitoring, *of RA bands* *(not occupancies !)*

a) ***private negotiation*** with the interferer
b) ***official reports*** ***to National Administrations***

Solution ***a)*** is attractive, being potentially the ***quickest*** one, but:

- it requires expensive hardware, skilled technicians, the ***identification*** of the interferer, ….
- it works only for ***terrestrial local*** interferers and only if an ***above regulatory frame*** exists …..

Solution ***b)*** opens a direct interaction with your National Administration

- the NA acts as a "third party referee", with a much higher level of compulsion against the interferer
- those officers can find in defending us a motivation for their skill in balancing the typical pressure made by the industry

As a by-product, Radio Astronomy can get a ***stronger credibility*** and possibly the ***vote*** of our National Administrations when they are called to take decisions (*one Nation = one vote*).